86805: Software Architectures for Robotics
Localization system for a wheeled humanoid robot

Date: Wed 23:55, 01.02.16

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Rollo - Humanoid robot

Odometry

Odometry is currently the most widely used technique for determining the position of a mobile robot. It mainly involves use of various encoders, for example on wheels, as sensors to estimate the robot's position relative to a starting or previous location. Usually, it is used for real-time positioning in the between the periodic absolute position measurements, for example GPS (Global Positioning System) provides absolute position feedback, however it updates at $0.1 \div 1s$ interval, during which odometry could be used for localization. One of the major downsides of odometry is its sensitivity to errors. There are various error sources discussed in section Odometry errors on page 4 in detail. One significant source of error influencing the accuracy of odometry that is worth mentioning however, is the integration of velocity measurements over time to give position estimates.

First the odometry based motion model for the robot will be derived.

The model is derived based on the following important assumptions:

1. The robot is a rigid body
2. The model represents a differential drive robot
3. There is no slip in the wheels
4. Both wheels are turning in the forward direction

A differential drive robot runs straight when the linear speed of both the left and right wheel is same. If the speed of one wheel is greater than the other, the robot runs in an arc. This derivation can be divided in three distinct cases of robot motion:

The basic premise for the odometry model of the Rollo humanoid robot is presented in figures (1) and (2).

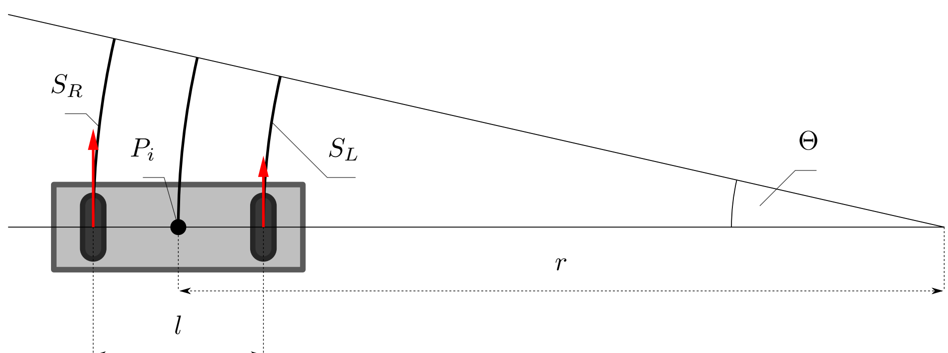

Figure 1: Odometry model with the simplified 2 wheel configuration for the right turn.

1. Clockwise direction
2. Counterclockwise direction
3. Straight line

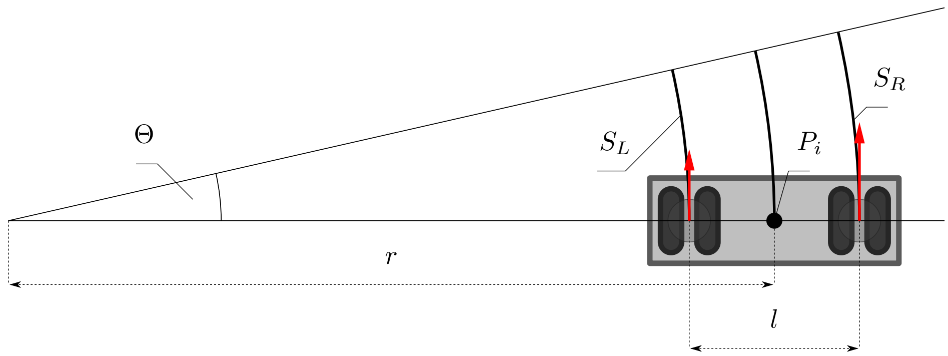

Figure 2: Odometry model with the simplified 4 wheel configuration for the left turn.

Clockwise direction

First, the case is considered when the speed of left wheel is greater than the right, and the robot will run in clockwise direction. Both right and left wheel will rotate around the same center of a circle.

P_i represents the initial position of the robot, defined by the center of the line joining two wheels, while l represents axle length, ergo distance between two wheels. S_L and S_R represent the distance travelled by left and right wheel respectively. Θ represents the angle of travel for both the wheels and r is the radius of travel from the center of robot. With encoder feedback from left and right wheel, S_L and S_R can simply be computed using equations (1) and (2)

$$S_L = \frac{n_L}{60} 2\pi r_L \tag{1}$$

$$S_R = \frac{n_R}{60} 2\pi r_R \tag{2}$$

where n_L and n_R are the revolutions per minute ([rpm]) of left and right wheel, and r_L and r_R are the radii of the 2 wheels.

S_L and S_R can be related to r and Θ using formulas (3) and (4)

$$S_L = (r + \frac{l}{2})\Theta \tag{3}$$

$$S_R = (r - \frac{l}{2})\Theta \tag{4}$$

The equations (3) and (4) above can be solved simultaneously to compute r and l.

$$r = \frac{l}{2} \cdot \frac{S_L + S_R}{S_L - S_R} \tag{5}$$

$$\Theta = \frac{S_R}{r - \frac{l}{2}} \tag{6}$$

Final position of the robot and its orientation can then be derived using basic trigonometry and geometry relations as displayed in equation (7):

$$P_f = \left[P_{ix} + r(1 - \cos(\Theta)), \quad P_{iy} + r\sin(\Theta)\right] \tag{7}$$

$$\text{final orientation} = \text{initial orientation} - \Theta$$

Counterclockwise direction

Similar derivation of the robot can be derived for counterclockwise rotation, when the rpm of right wheel is higher than that of the left wheel. The relations for final position and rotation are as follows for this case:

$$P_f = \begin{bmatrix} P_{ix} - r(1 - \cos(\Theta)), & P_{iy} + r\sin(\Theta) \end{bmatrix} \tag{8}$$

$$\text{final orientation} = \text{initial orientation} + \Theta$$

Straight line motion

$$P_f = \begin{bmatrix} P_{ix} + S_L(\cos(\Theta)), & P_{iy} + S_L\sin(\Theta) \end{bmatrix} \tag{9}$$

$$\text{final orientation} = \text{initial orientation}$$

Odometry errors

This method is sensitive to errors Rapid and accurate data collection, equipment calibration, and processing are required in most cases for odometry to be used effectively straight forward to implement

Odometry Error Sources Limited resolution during integration (time increments, measurement resolution). Unequal wheel diameter (deterministic) Variation in the contact point of the wheel (deterministic) Unequal floor contact and variable friction can lead to slipping (non deterministic)

The errors can be divided into systematic and random. Three main sources of systematic errors in odometry:

- Distance
- Rotation
- Skew

Last two more significant with time.

Conclusions